TRANSACTIONS
OF THE
ILLUMINATING ENGINEERING SOCIETY

FOUNDED IN LONDON 1909

INCORPORATED 1930

CONTENTS

	Page
Presidential Address, by W. J. Wellwood Ferguson, M.B., Ch.B., *(Fellow)* - -	1
Additions to List of Members - -	7
Fellowship - - - - - -	8
Register of Lighting Engineers - -	8
Some Developments in Factory Lighting, by T. S. Jones, *(Member)* - -	9
Blended Light, by S. Anderson, B.Sc., A.M.I.E.E., *(Member)* - - - -	15
Lighting in an Explosives Plant, by R. W. Middleton, M.I.E.E., and W. E. Harper, B.Sc. (Eng.), Ph.D., A.M.I.E.E., *(Member)* - - - - -	23
Opening Sessional Meeting - -	36

VOLUME XVIII
No. 1 — 1953

32 VICTORIA ST
LONDON, SW1

Annual Subscription to Non-Members - £2.2.0
Price per Number to Non-Members - 5s. 0d.

The I.E.S. Council and Committees

Session 1952-1953

Council

President :—W. J. WELLWOOD FERGUSON, M.B., Ch.B. (*Fellow*).

Vice-Presidents :—A. G. HIGGINS, M.Sc. (*Fellow*), E. C. LENNOX (*Fellow*), A. H. OWEN (*Fellow*), J. F. STANLEY, B.Sc. (Eng.) (*Fellow*), W. J. P. WATSON (*Fellow*).

Members of Council :—

Elected Members:—

D. S. ALLOM, S. ANDERSON, A. D. S. ATKINSON, G. G. BAINES, S. S. BEGGS, B. F. W. BESEMER, N. BOYDELL, F. M. HALE, W. E. HARPER, P. HARTILL, R. G. HOPKINSON, T. S. JONES, R. A. LOVELL, J. S. MCCULLOCH, L. H. MCDERMOTT, A. R. MCGIBBON, A. H. OLSON, A. G. PENNY, C. W. M. PHILLIPS, W. T. F. SOUTER, W. R. STEVENS, J. W. STRANGE, D. L. TABRAHAM, H. C. WHITE.

Ex-Officio Representatives of Centres:—

R. S. HAZELL (*Bath and Bristol*), E. H. NORGROVE (*Birmingham*), A. J. DALTON (*Cardiff*), H. BUCKLEY (*Edinburgh*), C. J. KING (*Glasgow*), H. V. SAYCE (*Gloucester and Cheltenham*), J. H. WEAVER (*Leeds*), H. J. RIGG (*Leicester*), A. V. MILTON (*Liverpool*), H. HEWITT (*Manchester*), G. KINGSLEY-LARK (*Newcastle*), P. L. ROSS (*Nottingham*), H. DICK (*Sheffield*).

Hon. Treasurer :—
W. J. JONES.

Hon. Secretary :—
H. C. WESTON.

Hon. Editor of Transactions :—W. E. HARPER.

All Past-Presidents of the Society are *ex-officio* Members of Council.

Committees

GENERAL PURPOSES COMMITTEE: W. J. Wellwood Ferguson (*President*), A. G. Higgins, E. C. Lennox, A. H. Owen, J. F. Stanley, W. J. P. Watson (*Vice-Presidents*), J. G. Holmes (*Past-President*), W. J. Jones (*Hon. Treasurer*), H. C. Weston (*Hon. Secretary*), C. J. King (*Glasgow Centre*), R. S. Hazell (*Bath and Bristol Centre*).

PAPERS COMMITTEE: S. Anderson, A. D. S. Atkinson, W. E. Harper, R. G. Hopkinson, T. S. Jones, A. R. McGibbon, J. M. Waldram.

EDUCATION COMMITTEE: R. O. Ackerley, G. G. Baines, S. S. Beggs, F. M. Hale, H. Hewitt, A. G. Higgins, J. T. MacGregor-Morris, C. W. M. Phillips, W. R. Stevens, J. W. T. Walsh.

I.E.S. CODE COMMITTEE: R. O. Ackerley, R. G. Hopkinson, F. C. Smith, W. T. F. Souter, D. L. Tabraham, H. C. Weston.

CENTRES JOINT COMMITTEE: One representative from each Centre. Council's Representatives: A. C. Higgins, E. C. Lennox, A. G. Penny.

(The President, Hon. Secretary and Hon. Treasurer are *ex-officio* members of all committees.)

Secretary :—G. F. COLE, 32, Victoria-street, London, S.W.1.

Presidential Address

By W. J. WELLWOOD FERGUSON, M.B., Ch.B. *(Fellow)*

The Approaches to Lighting

It is my duty first of all to express to the Society my consciousness of the great honour it has conferred upon me. Standing before so many whose knowledge of physics, physiological optics and lighting generally is so much greater than mine, I feel fully aware of the difficulty of my task, and can only hope that my position as what might be termed an informed outsider may have given me a perspective view of a somewhat unbiassed nature. I feel this honour and my own insufficiency the more in that—I believe I am right in saying—the only ophthalmic surgeon who has hitherto been elected to this office is one of the Society's founder members, my distinguished colleague Sir John Parsons.

Last year, in his address, our immediate Past President concluded his remarks by saying "We have enabled the common man to spend many hours in a kind of light to which his eyes are as yet unaccustomed or unsuited; we have inflicted non-uniform spectral distribution on him; we have provided conditions of extreme glare as a commonplace; we try to alleviate his lot and to make his visual task easier, but often we only give him more and more artificial light in which he becomes more efficient and more automatic."

These words were part of his plea for the greater use and investigation of natural lighting, and for greater co-operation between the architect and the illuminating engineer. I do not propose to pursue further the subject of natural lighting, but the remarks I have quoted suggested that I might discuss with you some of the many other aspects of lighting which emphasise the need for co-operation between representatives of widely differing interests. Many of them have special reference to a factor which will always tend to complicate the work of the scientist and to irritate the engineer. I allude, of course, to the human factor, which—in my view fortunately—will always preserve the practice of illuminating engineering as an art as well as a science.

The problems of lighting are full of complexity. Satisfactory lighting must be efficient; it must be comfortable; it must be harmless; it must usually be economic; and it should give a certain degree of aesthetic satisfaction. The problems must thus be approached along several distinct and separate lines; among them are the physical, the physiological and the psychological—though I would prefer another name for the latter as the word psychological has nowadays become too much associated in the public mind with such things as "complexes" and "fixations." Perhaps a better term would be the artistic approach. These three approaches to lighting were well illustrated by the excellent papers of Stiles, Logan, and Kalff at the recent Summer Meeting of this Society at Eastbourne.

In recent years the problems of illuminating engineering have been increased by the widespread introduction of fluorescent lighting and television. Questions regarding the spectral composition of the light emitted by the fluorescent lamp and the properties of this light source as a begetter of flicker, have arisen or have been postulated anew. Also, the possible relationship of fluorescent lighting to visual fatigue or even to pathological effects has been suggested. The application of fluorescent lighting for special industrial requirements, such as coal mining and weaving, calls for special consideration, to say nothing of the aesthetic problems raised by the effect of lights

Presented at a meeting of the Society held in London, October 14, 1952.

of different spectral distribution on such mundane things as food, decorations, and feminine complexions.

As many investigators have pointed out, human response to given levels of illumination varies not only between different individuals, but also in the same individual at different times. The study of dark adaptation also shows this in a remarkable manner, some subjects showing diurnal, and possibly also seasonal, variations.

Colour variations between individuals are even more frequent. Not only are there variations in the efficiency of colour vision, but the phenomenon of colour adaptation—so well illustrated by Halbertsma at the 1948 Meeting of the Commission Internationale de l'Eclairage in Paris—may influence both the judgment and the effect of colour values.

Apart from these variations in the response of the individual to lighting, there are also the different forms of expression of visual fatigue, so often popularly summarised by the term "eyestrain."

The assessment of such fatigue is, however, no simple task. In the first place, it is by no means easy to determine in a task involving visual concentration, how much of the so-called fatigue is associated with the visual task *per se*, and how much is due to the degree of mental concentration called for, or to the boredom which may be engendered by work of a dull and repetitive nature.

Pure visual fatigue may be due to imperfectly corrected, or uncorrected, errors of refraction of the eye; to imbalance of the extra-ocular muscles; to fatigue of the extra-ocular muscles; to faulty positions while performing the task, or to defective lighting. By the latter I do not imply only insufficient lighting, but include excessive light, and light badly distributed within the field of vision producing glare, faulty contrasts, and adaptational difficulties; the latter is frequently met with in television viewers. The possibility of retinal fatigue will be referred to later.

The question of pathological effects from fluorescent lighting, and in particular from any ultra-violet fraction thereof, is one that has been raised from time to time, more especially on the Continent. When considering this it may be of interest to review briefly the degree of penetration into the eye, and the effects of the various bands of the electro-magnetic spectrum.

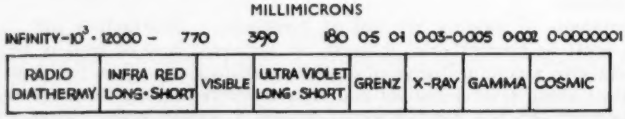

Fig. 1. The electro-magnetic spectrum. The divisions are not drawn to scale.

The visible, or light waves form only a small part of this spectrum and range from 7,700Å at the red or long end, to 4,400Å at the short or violet end. Beyond the red end of the spectrum are the infra-red rays, both short and long, followed in turn by the diathermy and radio waves. At the short end, the visible violet waves are followed by the ultra-violet band, divided into the long ultra-violet, from 4,000 to 3,200Å and the short ultra-violet from 3,200 to 1,900Å. Further along the scale in the short direction come the grenz, the X, the gamma and the cosmic rays, in that order. In addition, there are the corpuscular equivalents of some of these rays—the beta or cathode rays, emanating respectively from radium, or from cathode tubes, and the neutrons released by atomic fission.

The eye is adapted to receive and perceive the visible waves, but many of the invisible waves also enter the eye to a greater or lesser depth. While these are not perceived, some cause pathological effects due to the destruction of tissue. The

susceptibility of certain of the ocular tissues to particular wavebands depends both on the degree of transmission and of absorption of the rays by these structures, the destructive effects being determined by the degree of absorption. For example, rays which pass through the cornea but which are absorbed by the lens would tend to leave the cornea unharmed, but might produce pathological effects in the lens tissue by which they are absorbed.

The radio and the longer diathermy waves pass through the eye without appreciable absorption, and therefore produce no harmful effects. On the other hand, the shorter diathermy waves induce heat in the anterior portion of the eye, and may produce cataract. Of the infra-red band, the longest rays are almost entirely absorbed by the cornea and the aqueous fluid; the shorter rays, particularly those around 10,000Å, penetrate to the retina. Nearly all the infra-red radiations are absorbed by the pigmented portions of the eye.

The degree of penetration and the effects on the eye of various wave bands

Rays	Penetration	Result
Diathermy	Whole Eye	Cataract
Long Infra Red	Surface	Burns
Short Infra Red	To Retina	Cataract Retinal Burns
Visible	To Retina	Visual Stimulus
Ultra Violet	Surface	Kerato-Conjunctivitis
Long Ultra Violet	Lens and Retina	None
Grenz	Surface	None
X	Whole Eye	Destructive Lesions
Gamma	Whole Eye	Cataract
Cosmic	Whole Eye	None
Corpuscular Equivalents		
Beta Cathode	Surface	Superficial Destructive Lesions
Neutrons	Whole Eye	Cataract

The lesions caused by infra-red radiations are of three varieties. First, superficial burns of the cornea; secondly, a form of cataract, first described as " glass-blowers cataract " and seen in glass-blowers and those in certain other occupations connected with open furnaces; third, burns of the retina, such as are sometimes met with in imprudent viewers of solar eclipses. The superficial burns and the retinal burns are more or less immediate effects. The former produce pain and other symptoms rapidly, while the latter cause a central scotoma (i.e., blind spot) immediately perceptible to the sufferer. The development of the cataract is quite different. It develops gradually over a period of years and is only seen amongst those who have been exposed to the rays over a very long period. Whether infra-red cataract is due to a selective action on the lens fibres, or to heating of the cornea and iris pigment is still a matter of some doubt.

Of the visible rays, some 70 per cent. of those at the long or red end of the spectrum are transmitted to the retina, the percentage being reduced to about 10 per cent. at the violet end. Under ordinary conditions, no organic lesion of the eye as a result of exposure to these rays has been established; and, again under ordinary conditions, the retina would appear to be immune from fatigue thereby.

After-images resulting from exposure to moderate or low luminances are very brief, but where there has been an exposure to a high luminance for a length of time

the after-image may be persistent for days, weeks or months, and can no longer be regarded as purely physiological. The researches of Wright and Stiles suggest that the colour changes associated with the after-images due to exposures to luminances exceeding 20,000 trolands may indicate a retinal breakdown of some nature.

Under experimental conditions, it would appear that the time of exposure is more important in the production of persistent after-images than is the absolute brightness. On the other hand, persistent after-images, lasting for days and causing for the time complete blindness, have occurred after momentary exposures to light of great brilliance, such as the flash of an atomic bomb.

It is difficult to say how far—if at all—persistent after-images can be described as retinal fatigue. Sir Frederick Bartlett has suggested the following as a definition of fatigue:—" Fatigue is a term used to cover all the determinable changes in the expression of an activity which can be traced to the continuing exercise of that activity under its normal operational conditions, and which can be shown to lead, either immediately or after delay, to deterioration in the expression of that activity, or, more simply, to results within that activity that are not wanted."

That the scotopic elements of the retina, that is to say the rods, are subject to fatigue within this definition can easily be demonstrated. A suitable test object, perceivable with one portion of the retina under scotopic conditions, will fade out, but be again perceived if the eyes are moved in such a way as to throw the image on another portion of the retina. The deterioration of dark adaptation in miners' nystagmus is probably also an expression of rod fatigue.

Turning to photopic vision, visual factors outside the visual task may undoubtedly make that task the more difficult; for example, " veiling glare " can reduce form vision, and by reducing retinal sensitivity interfere with the visual task. In the same way adaptational conflict within the retina, such as can be caused by faulty relationship between the visual task and its surround, or by unduly bright objects or light sources in the peripheral visual field, will lead to difficulty both in concentration and in the performance of the visual task, and in extreme cases to failure of the ability to continue it.

Interferences of these types, which lead to " visual " fatigue in the sense that they

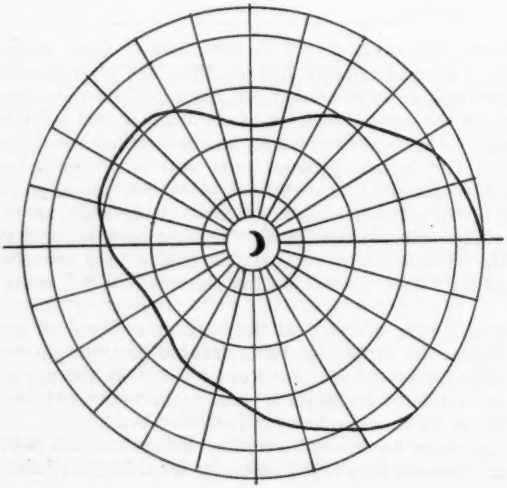

Fig. 2 Field of vision of right eye of a patient who suffered retinal burns as the result of viewing a partial solar eclipse through a piece of so-called " furnace glass." There is a small crescentric blind spot near the point of fixation, representing the area of burned retina. Both eyes were affected.

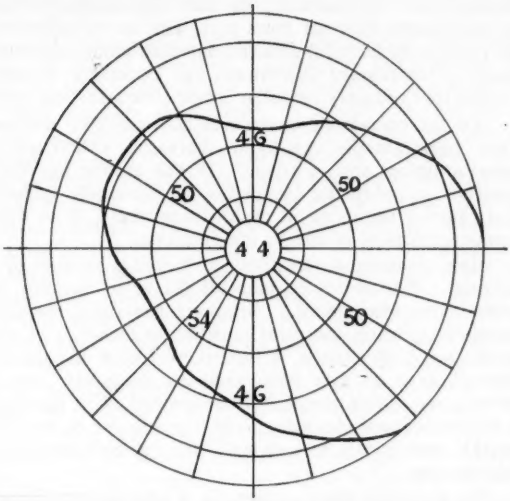

Fig. 3. Normal field of vision of right eye showing the local variations in flicker perception. Note that the central area has the lowest figure.

lead to a deterioration in the expression of the visual activity, can hardly be described as demonstrating fatigue of the retina within its normal operational conditions.

How far retinal burns resulting from exposure to the sun's radiation are due to the shorter infra-red rays, as opposed to the visible and ultra-violet bands, has not so far been precisely determined. It has been observed that the experimental production of retinal lesions in rabbits is determined rather by the energy value of the radiation than by its wavelength. Of the energy reaching the earth's surface from the sun, 55 per cent. is in the infra-red and only 39 per cent. in the visible range.

In view of the possible objections to lighting from fluorescent discharge tubes, it may be well to consider the transmission and absorption of the ultra-violet band in somewhat greater detail. These waves vary in wavelength from about 4,000 to 1,800Å. Most of the longer waves are absorbed in the lens, but are not known to have any pathological effect. The shorter waves of 3,200Å or less, are mainly absorbed in the cornea and thus do not reach the lens.

The effects of over-absorption of these rays are exemplified by so called "snow-blindness" where the radiations derive from the sun, and by "electric ophthalmia" resulting from exposure to welders' arcs or mercury-vapour lamps. In both, the lesions are in the superficial layers of the cornea and are accompanied by acute symptoms which appear after a latent period of some hours. It has long been known that the absorption by the lens of the shorter ultra-violet waves would cause changes therein. Fortunately, the amount of radiation necessary to produce such a harmful effect is three times greater than that which would produce a threshold response in the cornea.

So far as the retina is concerned, there is no evidence of any lesion being produced by the ultra-violet waveband. It is considered that only about 3 per cent. of what may be termed the "abiotic" ultra-violet rays—that is to say the shorter ones, which are the only ones known to have a destructive effect on the tissues—reach the retina. It is therefore extremely unlikely that any pathological effect in the deeper tissues could occur.

The emission of ultra-violet light from fluorescent tubes is confined to the longer wavelengths and it is, in fact, less in intensity than that present in daylight in a clear

atmosphere. In addition, the fact that ordinary window-glass, or crown glass, acts as an effective filter for these rays, adds to the safety factor. It would seem then that the chances of harmful effects from ultra-violet radiation from fluorescent tubes, except under extraordinary conditions, are extremely unlikely. It may be mentioned in passing that ordinary tungsten lamps emit infra-red rays.

Of the remaining wavebands little need be said as they do not concern us here. They penetrate the eye to an increasing extent and may cause destruction of the anterior tissues and cataract. In this atomic age the effect of the gamma rays and neutrons in producing cataract is of increasing importance; recent evidence suggests that cataract occurring in cyclotron workers, or in those in the neighbourhood of an atomic explosion, is due to the neutrons.

The question of sensitivity to flicker is another of the issues raised by fluorescent lighting. The ability to perceive flicker of varying periodicity differs from point to point in the visual field. Speaking generally, the central area is the least, and the peripheral portion the most sensitive to flicker. A source of flicker at a wide angle to the point of fixation is thus more likely to cause offence. ("Flicker fields of vision" have of late been used as diagnostic aids in various conditions.) The stroboscopic effect sometimes complained of in fluorescent lighting is, like flicker, due to its intermittent character. It is by no means peculiar to fluorescent lighting and at suitable speeds can be seen with any intermittent light source, whether fluorescent or incandescent.

To go to the other extreme, it is interesting to note that lack of light may produce certain untoward effects. The condition known as miners' nystagmus is generally accepted as being due to years of work in illumination so low that it precludes the normal use of macular vision. Involuntary rotational movements of the eyeballs, a falling-off in the speed and efficiency of dark adaptation, together with anomalies of binocular vision are among the ocular signs of this distressing condition.

I have so far dealt with the human factors from the pathological aspect. It is well, however, to recall the numerous physiological phenomena which accompany the act of vision—chromatic aberration, dark, light, and colour adaptation, simultaneous and successive contrast, after-images, complementary colours, the many entoptic phenomena and the effect of glare, to mention but a few. If we add to these the fact that all visual stimuli have to be transmitted to the brain to be appreciated and interpreted, we realise how varied, and we might almost say unpredictable, is the human response to light.

Evans, in his address to the recent Stockholm Session of the C.I.E., aptly quoted the old Arabian proverb "The eye is blind to what the mind does not see." We are all conditioned in this respect by our preconceived ideas and tend to see what we expect to see rather than what is actually there, and thus to interpret the visual stimulus in the light of our past experiences.

I have endeavoured in these few remarks to indicate the main approaches to the problems of illuminating engineering, and have dealt in some detail with a few of those with which I am daily brought into contact. My purpose in so doing may become more evident in a brief recapitulation.

The physico-physiological approach is based on the measurement of the response of the visual apparatus to known stimuli and, so far as is possible, judgment of the effect of such responses is in terms of efficiency or of fatigue.

The lighting engineer seeks for a formula whereby the recommendations of the physiologist may be converted into terms of the illumination—or shall I say the brightness—necessary for the particular tasks in hand.

To the manufacturer the problem is one of designing and constructing the necessary light sources and fittings with which this demand may be met.

Whether or not the practical result is successful depends on many variable factors,

and while the result may be physiologically efficient, it may at the same time fail to be either economic or aesthetically satisfying.

The artistic approach is of itself a fascinating study, yet one that is even more full of the pitfalls and vagaries of human variation. Colour in lighting and in decoration may be used to create the illusion of warmth or of coolness, as well as of height and distance. It may also engender cheerfulness or gloom. It can subtly emphasise one part of a subject, or conceal another. Theatre lighting, an art in itself, gives perhaps the best example of what can be accomplished in this field. On the other hand, the purely artistic approach, whilst it may provide aesthetic satisfaction, may fail to be economic and may, from the practical viewpoint, be inefficient. Again, the effective utilisation of natural daylight calls for a combination of all these approaches, and an architectural one as well.

This, then, is my thesis. This Society exists largely to provide a forum where all interested can meet and exchange views on common problems. Sir John Parsons, in his address to the Society in 1943 said of Mr. Leon Gaster that "His breadth of vision enabled him to recognise that good lighting included physiological, pathological, psychological, and even aesthetic factors." Sir John in his conclusion suggested the need for an Architectural and a standing Physiological Committee. I would like to go further. The success of the Society cannot be maintained by Committees alone. The Society as a body is the link which can bind all these varied interests together; in that lies its importance. Its hope for the future lies in ever extending and widening its field of interest, and in including among its members, so far as is possible, an ever increasing number of active and interested representatives of all these various spheres.

Additions to the List of Members

The following applicants have been duly elected by the Council to membership of the Society, and their names have been added to the list of members:—

CORPORATE MEMBERS:—

Anderton, A. ..... "Brooklyn," Sandyway, Prestwich, LANCS.
Benson, J. C. ..... "Westward Ho," Rose Hill, Marple, CHESHIRE.
Berson, M. L. ..... 205, North Street, Sheepscar, LEEDS, 7.
Bouchier, C. T. ..... "Aireville," 155, Aughton Street, Ormskirk, LANCS.
Bryan, J. I. ..... 38, Oakwood Drive, Fulwood, Preston, LANCS.
Burgess, H. ..... 14, Barnsdale Avenue, Thingwall, Wirral, CHESHIRE.
Chambers, A. N. ..... 388, Leek Road, Hanley, STOKE-ON-TRENT.
Conlan, P. J. ..... 6, Duncombe Road, Forest Town, Johannesburg, S. AFRICA.
Cowan, A. ..... 16, Medway, LIVERPOOL, 15.
Cutts, R. ..... 1, Herringthorpe Avenue, Rotherham, YORKS.
Davies, S. ..... "Northdale," Ridleyway, Bishopston, SWANSEA.
d'Netto, H. M. ..... 18, Lincoln Road, SINGAPORE, 11.
Field, C. M. ..... "Long Furlong," Gotherington, Nr. Cheltenham, GLOS.
Fisher, C. G. ..... 276, Hunsworth Lane, CLECKHEATON.
Gibson, R. W. ..... "Kenwood," 127, Upper Selsdon Road, Sanderstead, SURREY.
Gladwin, V. G. ..... 1, Carill Gardens, Fallowfield, MANCHESTER, 14.
Green, C. F. ..... 8, Northfield Road, GLOUCESTER.
Heafey, T. W. ..... 95, Portland Road, NOTTINGHAM.
Jones, J. E. ..... 21, Park Road, BELFAST.
Jones, T. ..... 20, Wren Street, West Gorton, MANCHESTER, 12.
Jordan, E. M. ..... General Electric Co., Ltd., Magnet House, Kingsway, W.C.2.
Le Marechal, S. H. ..... 73, The Triangle. Malmesbury, WILTS.
Maidman, A. A. J. ..... 23, Brixham Gardens, Ilford, ESSEX.
Moran, E. ..... 63, Hough Lane, Bramley, LEEDS.

O'Mahony, J. F. ..... 89, Ballymun Road, Glasnevin, Dublin, EIRE.
O'Neill, G. H. ..... 180, Philipsburgh Avenue, Fairview, Dublin, EIRE.
Pindar, I. ..... 23, Clarendon Street, LONDON, S.W.1.
Rogers, E. H. ..... 38, Tweedmouth Road, Plaistow, LONDON, E.13.
Sanford, B. T. J. ..... "Erroldene," 36, McDonald Road, Durban, Natal, S. AFRICA.
Scholey, G. ..... 1097, Leeds Road, Thornby, Bradford, YORKS.
Tucker, E. ..... c/o United Engineers, Ltd., P.O. Box 115, Kuala Lumpur, MALAYA.
Wallace, J. ..... 84, Grove Park Road, Mottingham, LONDON, S.E.9.
Williams, A. ..... 41, Cannon Street, Preston, LANCS.
Wilson, J. R. ..... "Maron," Pilton Marsh, Pinhoe, Nr. EXETER.
Wingrove, A. G. ..... 305, Compton Buildings, Compton Street, LONDON, E.C.1.
Wood, D. A. ..... 11, Brandon Street, EDINBURGH, 3.

STUDENT MEMBERS:—

Cutts, B. ..... 1, Herringthorpe Avenue, Rotherham, YORKS.
Dolan, A. ..... 21, Sexa Street, Openshaw, MANCHESTER, 11.
Dunkley, I. ..... 12, Lavender Avenue, Worcester Park, SURREY.
Varney, W. A. ..... 262, Warminster Road, SHEFFIELD, 8.

Fellowship

The Council has accepted the following applications for Fellowship of the Society:—

Mr. W. E. Rawson-Bottom.
Mr. L. Knopp.

Register of Lighting Engineers

The Council has accepted the following applications for inclusion on the Register of Lighting Engineers:—

Mr. R. C. Pennington, Mr. J. F. G. Kissel, Mr. C. Lockhart,
Mr. J. C. Cahey, Mr. A. J. Dickenson.

Some Developments in Factory Lighting

By T. S. JONES *(Member)*

It is peculiar that although much has been written in the past 10-15 years about detailed features and problems of factory lighting, a comprehensive paper dealing with the subject has never been presented at a sessional meeting of this Society. The reason may be that most lighting engineers are so familiar with some parts of the subject that it lacks attraction. A review of changes over a period may serve to disclose trends, and to separate these from experimental ideas which may fail to become established as accepted forms of practice.

In the pre-war days of the early thirties, with only filament lamps generally available as electric light sources, a great number of factories used light only as a small supplement for fading daylight and then often only in local or localised fashion. There were comparatively few installations of general lighting except in those industries where work occurred throughout the night.

During the middle and late nineteen-thirties electric discharge lamps were introduced and were used to some extent in industry. Although much more efficient than filament lamps, the light from them was of poor colour quality.

The importance of monochromatic or near-monochromatic light for some operations was, however, appreciated, and discharge lamps were used, for example, in ferrous foundries where the sharper definition produced on low contrast objects such as mould details was of some value.

Filament lamps and mercury vapour lamps were blended with considerable success for lighting in many industries where good colour rendering was not very important. Blending and electrical control were sometimes combined within a discharge lamp, the filament serving both to improve the colour quality of the light, and to provide near unity power factor electrical control—although with somewhat higher loss than that with inductive control. Blending was also achieved by placing both lamps in one reflector or by the use of separate reflectors, each system being suitable for different conditions.

The introduction of the tubular fluorescent lamp with its excellent colour rendering properties, low power consumption, large luminous area and correspondingly low brightness, diverted attention from high-pressure mercury vapour lamps and blended lighting, except for those situations where atmospheric conditions, high mounting position, or other physical features made the use of fluorescent lamp equipment impracticable.

Development of fluorescent lamps in this country was limited during the war years to the 5-ft. 80-watt lamp, and to one colour—"Daylight." Much interest was, however, shown in American practice because of the adoption in that country of the 4-ft. 40-watt lamp as the standard general lighting fluorescent lamp.

Subsequent analysis of the apparently higher efficiencies of 40-watt lamps compared with those of the 80-watt lamp showed, however, that their performance—when all the relevant factors were included—was not so attractive for equipment operating on a 200/250 volt supply. As a result, although 40-watt lamps are very useful for particular applications, their industrial use is comparatively limited.

In the matter of colour, too, there were expectations of considerable application for many varieties of white and coloured lamps, but here again experience has proved the demand to be limited. For general industrial lighting "Daylight" or "Natural"

The author is with Crompton Parkinson, Ltd. The manuscript of this paper was first received on October 1, 1952, and in revised form on November 5, 1952. The paper was presented at a meeting of the Society held in London on November 11, 1952.

The discussion on this paper and on those by S. Anderson (p. 15), and R. W. Middleton and W. E. Harper (p. 23), which were presented and discussed at the same meeting, appears on page 29.

Fig. 1. Use of local fluorescent lamp units for examination of cotton goods. General lighting by tungsten filament fittings.

lamps are generally used, with colour-matching tubes being usefully employed when accurate colour rendering is more important than efficiency.

In spite of the widespread adoption of fluorescent lamps for industrial lighting since the war, the use of filament lamps continues; they are still used, and probably will continue to be used, both for general and for local lighting.

The early fears that colour differences would prevent general and local lighting being provided by fluorescent and filament lamps, or vice versa, were soon dispelled and each source has particular virtues for such work. For example, the small, easily controlled filament source can be used to provide high-lights and sharp contrasts often

Fig. 2. High-intensity lighting from fluorescent units over localised area of factory.

essential for fine work. Again, used locally or in localised arrangements, fluorescent lamps have colour value which proves most useful for such operations as examination of cotton goods where incipient mould can be detected far more easily with these lamps than with filament sources (Fig. 1). Their localised use for high-intensity lighting from low mounting heights or for the reduction of shadow is illustrated in Fig. 2.

The use of fluorescent lamps to *produce* shadows is not so widely known, but the example from the worsted industry of a burling and mending room shown in Fig. 3 illustrates how the shadow of weft threads can be accentuated by suitably placed lamps to facilitate this visual task even on single-colour material.

The changes of light source have being followed by changes in the design of lighting fittings. Development of filament and of discharge lamp fittings has been directed

Fig. 3. Fluorescent lamps positioned to produce shadows for greater ease of seeing in a burling and mending room.

mainly to improving the features which reduce maintenance, such as low-temperature wiring chambers, detachable reflector arrangements, etc., and it is notable that the majority of reflectors installed to-day include such features in one form or another; very few of the older single-piece designs are used for lamps larger than 80-watt mercury or 100-watt filament size.

Detailed comments on fittings design are outside the scope of this paper, but some reference to the general trends of fluorescent lamp fittings design is important.

From the rather crude inverted metal troughs surmounted by boxes containing

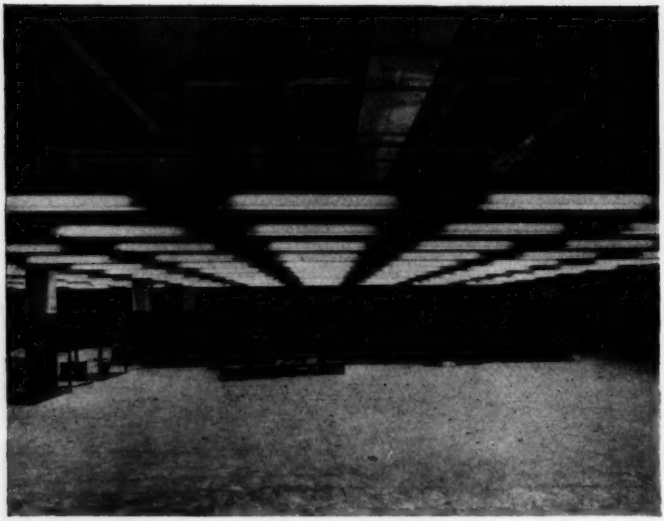

Fig. 4. Installation of continuous trunking using fluorescent lamps in opal acrylic reflectors.

similarly crude designs and arrangements of chokes, condensers and starter switches, has been evolved a variety of fittings made of several materials with various finishes.

The introduction of slim, brick and composite control gears made it possible to improve the appearance of trough reflectors, which are now more slender than the early patterns.

The original painted finish of these reflectors has been superseded by modern processes of pre-treatment combined with high-gloss stoved finishes which are remarkably resistant to damage by abrasion, impact or corrosion.

Vitreous enamel treatment of steel, whilst resulting in a heavier reflector, is widely accepted where hard wear and moisture may be expected to damage other forms of finish, but in the elongated form of fluorescent fittings careful design is necessary to provide strength if transit and handling damage is to be avoided.

Where extreme resistance to acids, alkalies and moisture is necessary, or where damage by impact or physical strain is likely to occur, white rigid PVC sheet is proving very useful. This material has certain thermal characteristics which limit its application, but these are not too severe to prevent its being used for industrial lighting in many locations.

Opal acrylic sheet, too, has a great number of applications, especially in the lighter industries and in factories where its translucent properties can be used with advantage to improve the brightness distribution of the surround, so leading to more comfortable seeing conditions.

Polystyrene has not been widely available in this country but American practice, which has now accepted the British views in regard to acrylic sheet, does not seem to have found the use of polystyrene as practical for industrial purposes as it has been for commercial lighting applications.

Used with several different types of lighting equipment, but particularly designed for use with fluorescent lighting, are the systems of continuous trunking developed in the last few years as a natural outcome of the desire to improve the appearance

and ease of installation by coupling together individual fluorescent fittings. Examples of continuous trunking systems are shown in Figs. 4 and 5.

These modern systems offer much advantage in large factories where it may be necessary to vary the plant layout and operational areas, particularly where such variations demand different standards of lighting or different fitting spacings.

During the period covered in this review there has been a marked increase of knowledge in relation to the many visual problems common to industry. The work of Weston and others has resulted in a rational relationship between object size and illumination for given degrees of contrast, and has provided a sensible basis for calculation in place of the purely arbitrary figures previously used.

Study of the effects on vision of light reflected from specular objects, and of the relationship of apparent source area to this problem, has helped to solve many problems in the printing and engineering industries. Often the solution is provided by using more than one type of source to produce the desired degrees of contrast.

Wider appreciation of the need for shadow to define form has resulted in greater directional control of light flux and, sometimes, in the need to avoid purely symmetrical layouts of high-diffusion general lighting.

Similar investigation into the problems of reflected glare from such surfaces as tracing cloth has resulted in directional control by suitably spacing and offsetting general lighting layouts in drawing offices.

Avoidance of direct glare is now a widely accepted elementary principle and the significance of reflected glare is much more widely studied in the approach to all industrial problems. To minimise glare troubles, control of the brightness of apparent sources now receives far greater attention than it used to do, and the use of diffusing screens of glass or plastic material and of louvres is fairly common, whilst the design of fittings to provide a reasonable amount of light in the upper portion of rooms allows brightness contrasts between lighting fittings and their backgrounds to be modified to comfortable limits.

The use of light colours for decoration of factory interiors is becoming wide-

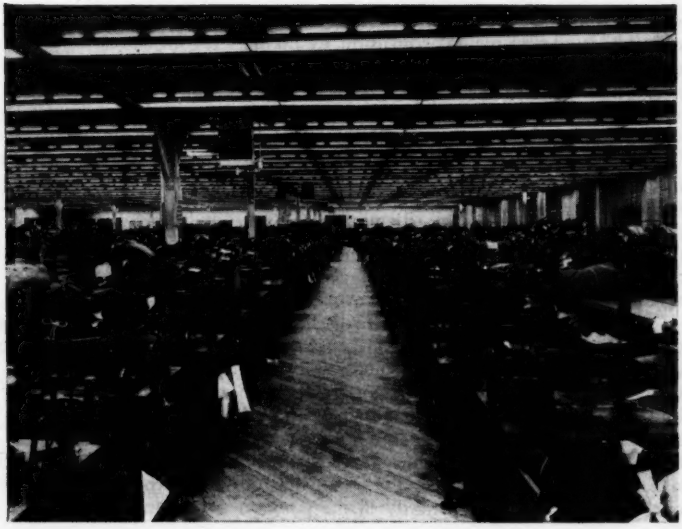

Fig. 5. Continuous trunking installation using slotted enamelled steel reflectors.

Use of light backgrounds to improve ease of vision.
Fig. 6 (left) General view. *Fig. 7 (right) Close-up view.*

spread not only because of the greater amount of light reflected from such surfaces, but also because they can provide comfortable visual and psychological conditions with resultant low rates of fatigue. Some interesting experiments have been made to prove the psychological value of using different strong primary colours on adjacent wall surfaces, and contrasting or harmonising these still further with the colours of structural features, ceilings and machines. There seems to be a danger, however, of causing visual and mental confusion by taking such measures too far, and it might do more harm than good to try such experiments in places where economic production is important.

The use of light backgrounds is often valuable, particularly where visibility depends upon viewing objects in silhouette. Local screens illuminated from the general lighting can greatly improve ease of seeing, whilst translucent panels, suitably illuminated from behind, are often used for silhouette examination, and even built into machines where the silhouette or profile is enlarged and sometimes projected on to a screen (Figs. 6 and 7).

Often windows of diffusing glass are used to allow daylight to provide luminous areas which, by night, can be replaced by blinds illuminated from inside the building, so allowing continuity of normal working conditions.

In conclusion, it should be realised that a successful approach to most industrial problems is based upon common sense, trained observation and a knowledge of the performance of available equipment. Any pre-conceived bias in favour of a particular type of source is liable to lead to disappointment, but the wide variety of lamps and lighting fittings now made enables most problems to be solved in a practical and economical manner. The common sense factor should prevent any striving for a theoretical perfection for which the cost of practical achievement is likely to be excessive. Trained observation is the result of study and experience and the ability to put oneself physically and mentally in the position of an operator.

Blended Light

By S. ANDERSON, B.Sc., A.M.I.E.E. *(Member).*

(1) Introduction

As the term "blended light" is not widely recognised, for the purpose of this paper it may be defined as light which is a mixture of the radiations from two or more sources which have dissimilar spectral characteristics. Frequently, but not necessarily, one source is an incandescent filament and the other a discharge lamp.

Blended light from artificial sources is used in a variety of applications, but the present paper is concerned specifically with their use in industrial lighting.

(2) Industrial Use of Blended Light

(2.1) Improvement of Existing Artificial Lighting

Probably the first use of blended light followed the introduction of the high-pressure mercury vapour discharge lamp. Industrial users of filament lamp installations found that the addition of a few 400-watt H.P.M.V. lamps brought a new vitality to their artificial lighting, and gave a desirable increase in illumination far more economically than would have been possible otherwise.

Satisfactory experience with the H.P.M.V. lamps as supplementary lighting sometimes led to the installation of these lamps alone for new premises or extensions to the works, but some blended installations of the type described continue to give satisfactory service.

(2.2) Colour Improvement with Discharge Lamp Installations

The wide use of H.P.M.V. lamps for industrial lighting is attributed to a number of advantages. Among them is the colour quality of the light which, in comparison with that of the filament lamp, appears to improve the visibility of fine detail, to reduce the colour contrast in comparison with natural light, and to give the factory a brighter appearance.

It is well known that the spectrum of the mercury discharge is unsuited to the correct rendering of colours, partly owing to the concentration of the radiation into well defined bands, and partly to the almost complete absence of red light. Thus where it is desired to take advantage of the high efficiency and other desirable characteristics of H.P.M.V. lamps but with improved colour rendering, a blend of light is necessary.

One often quite important reason for modifying the mercury discharge light is to secure a more healthy and normal appearance of the complexion, for even where men only are employed, there is sometimes a definite adverse reaction to working in a light which is far from flattering either to the complexion or to food. Even when there is no advantage to be gained on the work, this reason alone may be sufficient to make colour improvement obligatory.

(2.3) Safety Lighting with H.P.M.V. Installations

The characteristics of H.P.M.V. lamps are such that after they are fully run up, even a momentary interruption of the supply puts them out for a minute or two before the conditions enable them to restrike, and this might lead to danger or spoilage. For this reason the use of additional tungsten filament lamps is a wise precaution to tide over the possible black-out period. If supply interruptions of more than

The author is with The General Electric Co., Ltd. The manuscript of this paper was first received on September 9, 1952. The paper was presented at a meeting of the Society held in London on November 11, 1952.

momentary duration are to be catered for, the filament lamps may be fed from an independent source—possibly in the form of a local generator or battery.

(2.4) Increasing the Red Content in Light from Fluorescent H.P.M.V. Lamps

Much has been achieved to improve the colour of light from fluorescent H.P.M.V. lamps by the introduction of phosphors giving a warm tone of light from the fluorescent lamp alone, but still the light so obtained lacks something of the warmth of filament lamp light. In particular the deep red content is weak, whereas in the filament lamp this forms a considerable component of the light. Perhaps in the future, developments will provide a fluorescent lamp whose light is so close in composition to that of the filament lamp that no advantage could be obtained by blending it with filament lamp light, but meanwhile blending is one way of achieving the result.

There may be some doubt of the need for such a warm tone of light in industry, but industrial reflectors for the combination have appeared on the market both on the Continent and in England, and quite apart from the simple ballast considerations covered later, there may well be found certain industrial applications for which this blend of light constitutes the closest approximation to the ideal yet known.

(3) Methods of Blending

If it is accepted that a certain blend of light is required to produce optimum illumination, it follows that the blend should be sensibly uniform over the working areas involved. This raises problems in the design and location of the lighting units. The design of a fitting to give a similar distribution of light from two separate sources of widely differing form is not easy when individual reflectors are used, and virtually impossible if a single reflector is used.

(3.1) Mercury/Tungsten Lamps and Fittings

The MAT. and MBT. range of lamps embody the high-pressure mercury and tungsten sources in one envelope, and provide blended light in a neat and compact form for housing in one reflector. In the two smaller sizes (MBT.) the filament surrounds the discharge-tube and the resultant light is well blended as it leaves the lamp. With these sources well-known types of dispersive or concentrating reflector can be used and no special problem arises.

In the 300- and 500-watt (MAT.) sizes, however, the filament is below the discharge-tube, and their light centres are about 95 mm. and 135 mm. apart respectively. Further, the discharge source is several inches long while the filament is in the conventional wreath shape. These lamps are used in basin-shaped vitreous-enamelled reflectors similar to those designed for the 250- and 400-watt MA-type lamps. Where the reflector is open, there are inevitably differences in the distribution of light from the discharge and filament sources due to the different source forms and light centres; the cut-off angles are also different, but these disadvantages can be avoided by the use of stippled-glass covers with some sacrifice in light output and concentration. No other practical solution for these lamps is known. A polar curve for such a unit is shown in Fig. 1.

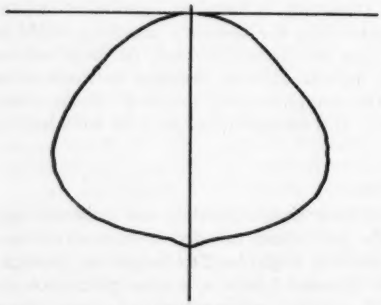

Fig. 1. Light distribution from 500-watt MAT. lamp in conventional reflector with diffusing cover.

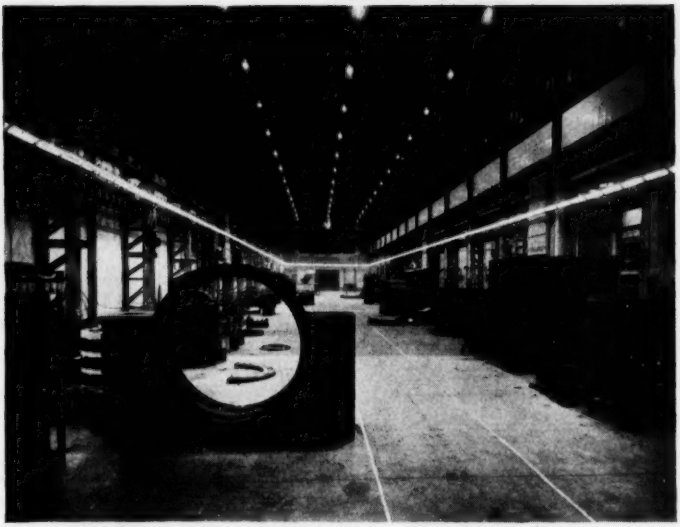

Fig. 2. View of an alternator erection shop lighted by means of 1kw. MB/V lamps overhead, supplemented by fluorescent lamps along each side wall.

(3.2) Separate Units

Where separate lamps are used to produce the blended light, each may be housed in a reflector of the normal dispersive type, and the distributions obtained are sufficiently similar to avoid noticeable variation in colour over the working plane when the reflectors are mounted in pairs or groups at each lighting point. If the individual reflectors are spaced, however, there may be noticeable colour variations unless the spacing is such that the units of each type taken alone constitute a system giving a sensibly even illumination over the whole area. Such an arrangement would involve a big increase in the number of lighting positions to be visited for maintenance, in addition to a higher installation cost. It may be appropriate where the second type of light source is installed at a later date than the first, but otherwise does not appear to merit adoption.

Objections have sometimes been expressed regarding the colour shadows which are unavoidable with spaced separate units, and have sometimes been commented upon where the separate units are grouped or paired. It seems possible that in certain operations these colour shadows would be troublesome, but no specific example of trouble is known, and it is thought unlikely that trouble would arise from this cause in any location where a mercury/tungsten system using separate units is likely to be employed.

There are instances, however, where the different types of light source are arranged quite separately, yet combine to give a very satisfactory result. One is illustrated in Fig. 2. Here the main overhead lighting is from high-pressure mercury lamps mounted at a height of 70 ft., while the side lighting at 30 ft. is obtained from continuous trough reflector lines housing twin 80-watt fluorescent lamps. With the overhead lights at such a great height, it was obviously desirable to add side lighting in order to improve the vertical plane illumination, and fluorescent lamps were chosen for their low brightness, high efficiency and the measure of colour improvement which they provide.

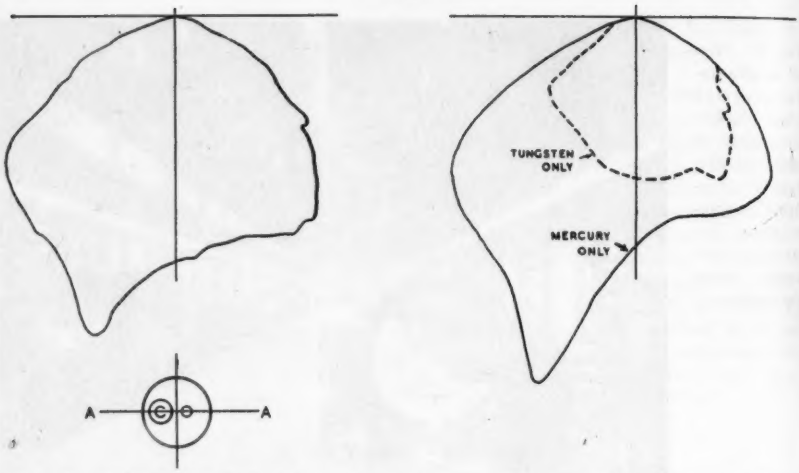

Fig. 3. (a) (left) Light distribution from mercury and tungsten filament lamps together, housed in a common reflector. (b) (right) Light distribution from each lamp separately in the same assembly as in (a). (Not to same scale.)

(3.3) Composite Units

Since it is desirable to arrange for the two light souces to be close together where they are in the form of separate lamps, four alternative reflector arrangements are possible:—

(i) The two lamps may be simply accommodated in a single reflector, one or both being offset from the vertical axis. Such an arrangement is unlikely to provide a symmetrical distribution of light, and cannot provide an even blend over the whole area unless a diffusing cover-glass is added. Fig. 3a shows an intensity distribution curve in the vertical plane through the two lamps from a unit of this sort without a diffusing cover, while Fig. 3b gives the distribution curves of the mercury and tungsten lamps separately. It is evident that the overall illumination provided will vary from point to point not only in intensity but also in blend.

(ii) The only practical method of avoiding these irregularities seems to be to house each lamp in its own reflector, and the two or more units in the cluster may be mounted simply on independent suspensions dropping from closely adjacent outlets. While there are no technical objections to such an arrangement, it has practical disadvantages in installation and servicing.

(iii) A preferable arrangement is illustrated in Fig. 4, where the separate reflectors are mounted on a common framework or channel and can be regarded as a single composite unit from an installation standpoint. In such designs advantage is taken of the higher light output ratio obtainable from the tubular MA-type lamps when used horizontally; in the second, the channel above the reflectors accommodates the control gear. Although the overall distribution of light from such units is not symmetrical in all vertical planes, it is symmetrical on that containing the long or the short axis, so that, with suitable orientation and spacing, good uniformity is obtainable on the working plane, and the units are convenient in distribution for the long bays into which factories are frequently divided. A typical polar curve is shown in Fig. 5.

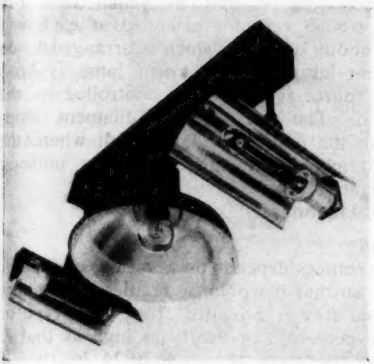

Fig. 4. A composite unit in which the channel above the reflectors houses the chokes.

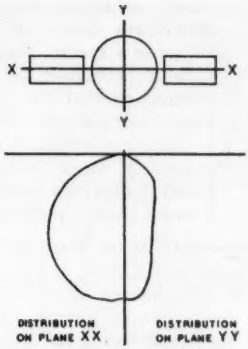

Fig. 5. Light distribution from the unit shown in Fig. 4.

(iv) Normally, owing to their different source dimensions, tungsten- and MA-type lamps are regarded as requiring quite different shapes of reflector to produce similar distributions of light, and general acceptance of this supposition is evident from the types of reflector on the market. In an attempt to produce a blended light unit in compact form economically, however, it became evident that conventionally shaped reflectors must be abandoned, and the simple rectangular unit shown in Fig. 6 was evolved.

This is of open-top construction, giving some upward light, and arranged so that the reflector section can be detached for maintenance without disturbing the lamps. The choke is housed in the void between the two inner reflector plates. All the reflector surfaces are in anodised aluminium of a grade giving a large diffuse component, and the light distribution from each source is surprisingly similar. The combined intensity distribution from the unit is practically the same in the vertical planes through the lamps and at right-angles. Fig. 7 shows the mean curve for these two planes. The overall light-output ratio is about 85 per cent., or 75 per cent. below the horizontal.

One other blended lighting unit falling within the category of com-

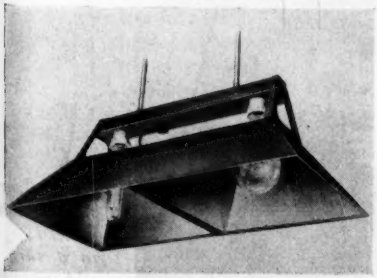

Fig. 6. A compact blended light fitting providing some upward light and housing the choke in the middle between the reflectors.

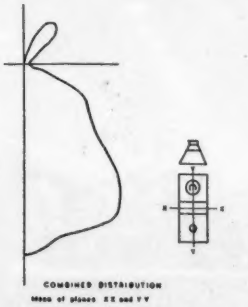

Fig. 7. Light distribution from the unit shown in Fig. 6.

bined industrial fittings of compact type is that in which two 4-ft. fluorescent lamps are housed in a trough reflector extended at each end to house a special filament lamp of about 70 watts, which is arranged to do duty as a ballast for the fluorescent lamp. The filament lamp is bowl silvered so that the light from this source is completely controlled by the metallised specular reflector above it. The light from the filament lamps is more concentrated than that from the fluorescent lamps, but where the mounting height is considerable compared with the spacing, a uniform blend is obtained on the working plane.

Figs. 8 and 9 show typical blended light installations.

(3.4) Proportions in the Mercury/Tungsten Blend

The best proportion of light from the two sources depends on a variety of factors, and is finally a matter of personal preference, so that it would be fruitless to attempt to lay down specific figures. If roughly equal flux is provided from each type of source, the blend has a red ratio of about 13 per cent., or nearly as high as that in daylight, but the combined efficiency will not be more than about 24 lm./w. If roughly equal power is employed in each source, the red ratio is reduced, but the efficiency is slightly higher.

In practice the proportions obtainable are limited by the lamp sizes available, but quite wide variations are possible, particularly if three lamps are used in each group. For instance, a unit for high mounting and high efficiency may house two 400-watt mercury lamps and a 1,000-watt filament lamp. Alternatively, for a warmer blend one may employ the two-lamp type of unit with a single 400-watt mercury lamp coupled with a 1,000-watt filament lamp.

To obtain a blend with a reasonable red ratio at the highest possible efficiency, it is necessary to employ the 1-kw. MB/V. mercury lamp with a 1,000- or 1,500-watt filament lamp and the total light output per unit becomes very large, but such a blended unit may well find application in some of the vast and lofty factories or aircraft assembly halls now becoming increasingly common.

Appropriate data is given in Table 1, which also includes corresponding data for

Fig. 8. Tungsten / mercury blended light in a turbo-alternator hall.

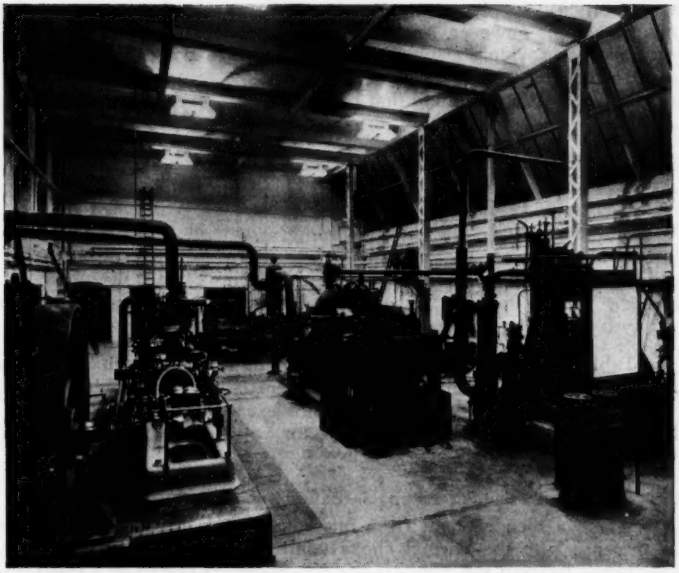

Fig. 9. Tungsten/mercury blended light from fittings of the type shown in Fig. 6.

a mercury/tungsten lamp and for an MAF/V. mercury fluorescent lamp for comparison, although the latter does not strictly fall within the scope of this paper.

Table 1.

Lamp combination	Total lamp light output	Combined efficiency*	Approx. red ratio
	(lumens)	(lm./w.)	
1×400w. MA/V. + 1×1000w. T.	32,200	22.7	14 per cent.
2× 400w. MA/V. + 1×1000w. T.	46,600	25.3	10 ,,
1×1000w. MB/V. + 1×1000w. T.	65,800	32.1	7.5 ,,
1× 500w. MAT/V.	10,500	21	8 ,,
1× 400w. MAF/V.	12,800	30.5	6 ,,

* Including choke loss.

(4) Subsidiary Considerations

While application effectiveness and efficiency are the principal considerations with which this paper is concerned, there are others of some importance.

(4.1) Power Factor Correction

Choke controlled mercury discharge lamps give a load power factor of 0.5 to 0.6, and it is necessary to correct this for the sake of wiring economy and usually to satisfy

the electricity supply requirements. With a blended light installation employing filament lamps however, since the latter operate at unity power factor, they may be regarded as providing a measure of power factor correction. Where the proportion of filament lamp load is adequate, therefore, the conventional capacitor correction may be dispensed with, assuming that both types of lamp are fed through common circuits.

Table 2.

Lamp combination		Approx. overall power factor
TUNGSTEN	MERCURY	
1× 500w.	1×400w.	0.85
1×1,000w.	1×400w.	0.93
1×1,000w.	2×400w.	0.85

Table 2 shows the overall power factor obtained with various combinations of high-pressure mercury and tungsten filament lamps. It will be seen that provided the wattage of the mercury lamps does not exceed 80 per cent. of the wattage of the filament lamps, the overall power factor will not be less than about 0.85. These values refer to a supply at 230 volts.

(4.2) Tungsten Filament Lamps as Ballast for Fluorescent Lamps

Where a blended light from this combination is desired, it is sometimes possible to dispense with the normal choke control. With normal 4-ft. 40-watt instant-start fluorescent lamps if the cathodes are pre-heated by means of a small transformer, starting and operation are satisfactory with a specially rated tungsten filament lamp as ballast, and an overall efficiency of over 20 lm./w. is obtainable. Special fluorescent lamps of a similar rating are also obtainable with which the filament heating transformer is unnecessary. These arrangements are limited to the 40-watt lamp, but they do provide the opportunity of obtaining blended light with economy in first cost. The power factor correction capacitor is unnecessary, as the combination operates at practically unity power factor.

(4.3) Lamp Replacement

Where the blended light units are easily accessible, the difference in the life of the mercury and filament lamps is probably unimportant. Where access is difficult or expensive, however, the shorter life of the filament lamp may be regarded as a disadvantage of the combined unit system of blended light, but it should be remembered that in an installation of filament lamps alone equally frequent access would be necessary for relamping. In any event, unless the situation is an unusually clean one, the reflectors and lamps should be cleaned certainly not less frequently than at 1,000 burning hours intervals, and it is wise to carry out group relamping at the same time.

(5) Conclusion

It is felt that while blended light is not very widely used in industry at present, it merits attention particularly in large areas where the mounting height is necessarily great. In such situations the use of large mercury lamps is attractive on most counts, and when suitably blended with filament lamps the resultant light is of good colour also.

The author wishes to acknowledge the assistance of the B.T.H. Co., Ltd., the Benjamin Electric Co., Ltd., Philips Electrical Company, and of colleagues in the General Electric Co., Ltd., from whom data and illustrations in the paper have been obtained.

Lighting in an Explosives Plant

By R. W. MIDDLETON, M.I.E.E., and
W. E. HARPER, B.Sc.(Eng.), Ph.D., A.M.I.E.E., *(Member)*

(1) Introduction[1]

In some industries operational factors limit the advantage which can be taken of recent progress in lighting practice. This is particularly true where explosion hazards are present and official regulations govern the design and installation of all electrical equipment. Such hazards occur in many industries, and the Factory Act of 1937 makes each industry responsible for assessing its particular hazards and for taking precautions adequate to meet them. To illustrate problems in the explosives industry this paper describes the lighting of one of the largest factories in Great Britain, where a wide range of industrial explosives and associated chemicals is manufactured.

The factory site can be divided into "safe" and "danger" areas. In the former are located main workshops, boiler stations, sub-stations, buildings where materials are processed before they are passed to danger buildings, research, administration and welfare buildings. Their lighting conforms to modern industrial practice and calls for no comment.

All buildings in which explosives are present are declared to be "danger" buildings. They are usually small in size and are isolated by surrounding earthen mounds; they are connected by roads, paths and/or narrow-gauge rail networks. Except over the small distances within or immediately adjacent to danger buildings, special precautions for lighting these roadways are unnecessary and standard street lighting fittings are used.

Manufacturing processes in some danger buildings are continuous; in others two shifts are worked, so that the importance of good artificial lighting for plant efficiency is considerable.

(2) Explosion Hazards

Industrial explosion hazards are varied and complex, but may be divided into two main groups:—

(i) Hazards in buildings or plants where gases, vapours or volatile liquids are present and may form an explosive mixture with air either at room temperature or at some higher temperature;

(ii) Hazards where dusts are in explosive mixture with air.

Either or both hazards may be present in explosives buildings, the degree of danger varying both with the type of explosive and with the operational process. Hazards are especially great where explosive dusts are present in the atmosphere; "dust clouds" may surround these buildings and extend over large areas.

The lighting fittings specified for the different buildings vary with the hazard, and are designed to prevent an excessive energy transfer (by electric sparks, arcs, heat or electrostatic discharges) initiating an explosion. It has been shown experimentally that very small energy transfers can cause self-propagating explosions in some atmospheres, less than 0.002 joule being sufficient to "ignite" some explosive mixtures.[2]

(3) Regulations

The installation of electrical equipment in the danger areas of an explosives factory is controlled by sections of several documents including the Factories Acts of 1937 and

Mr. Middleton is with the Nobel Division and Dr. Harper with the Plastics Division of Imperial Chemical Industries Ltd. The manuscript of this paper was first received on August 15, 1952. The paper was presented at a meeting of the Society held in London on November 11, 1952.

1948, the Explosives Act of 1875, the Explosives Substances Act of 1923, the Home Office Memorandum on Electric Light and Power in Explosives Factories and various B.S.I. and I.E.E. specifications and regulations.[3]

Within the authors' Company, these various regulations are supplemented by a Company Schedule which groups the danger buildings into three classes according to the hazards, and specifies the types of fitting which may be used in the buildings of each class:—

Class 1.—Explosives buildings lighted by either:—
- (a) External fittings suited to the particular operating conditions and lighting through fixed windows or roof-lights, or
- (b) Wall-mounted flameproof fittings, so installed that only the wall plate and glass are within the building, lamp renewals and maintenance being effected from outside.

Class 2.—Explosives buildings lighted by either:—
- (a) Pendant flameproof well-glass fittings, or
- (b) Wall-mounted bulkhead flameproof fittings.

Class 3.—Explosives buildings lighted by approved pendant dust-tight fittings.

The fittings used in this factory and described in Section 4 have been selected or specially designed to conform to the requirements of these three classes.

(4) Design and Installation of Lighting Equipment in Danger Buildings

In view of the safety regulations which must be observed in all danger areas, it is not surprising that lighting practice in the explosives industry is less advanced than in industries where there are no explosion hazards and no restrictions on equipment or installation. As late as 1937 the illumination in danger buildings rarely exceeded 1 lm./ft.^{2}, and not infrequently the only artificial light entering the building came from simple well-glass units mounted outside fixed windows. During the past ten years advances have come from improvements in equipment appropriate to the different hazards, and in particular from official recognition that in some buildings dust-tight fittings may replace the flameproof units previously used. The average illumination in many danger buildings is now 6-8 lm./ft.^{2}, and it is possible to study the visual tasks and, within limits, plan the lighting accordingly. Illumination values of this order are adequate for many operations in explosives factories, but where the visual task is particularly exacting—as in fuse assembly—a much higher local illumination is provided.

(4.1) General Design Features of Lighting Equipment

Before describing units typical of the three classes of equipment, it will be convenient to discuss design and installation details which are common to different fittings.

Experience has shown that the shock waves from an explosion in an adjacent building can cause heavy pendant fittings to "bounce" and strip the thread of the supporting conduit. Should this occur, the fitting will fall and break the wiring which will then be exposed. To guard against this, all pendant units are now made as light as possible and safety suspension wires are fitted.

Should dust deposits form on fittings, the operating temperature may rise and the risk of ignition be increased; the specification of smooth exterior contours minimises this danger.

To ensure dust-tightness, the standard practice in this factory requires all joints to be made by machined faces which are wiped with a high melting-point grease before the fitting is assembled. When specially authorised by H.M. Inspector of Explosives, a gasket may be used in lieu of machine-faced joints provided that (a) the

gasket is not perishable; (b) the joint so made is not required to be broken for normal maintenance; and (c) the dimensions of the flanges and housings of the joint are adequate for dust-tightness.

In some recent designs of fittings, acrylic plastic covers or glazing are used. Before this material could be approved for use in fittings installed in danger buildings, it was necessary to establish that with approved maintenance there was no danger of igniting powders by the electrostatic charge which can be induced on the sheet, and also that the acrylic cover or glazing would not itself be ignited should an electrical failure cause molten metal to fall from the lampholder or wires.

The temperature rise of fittings in all danger buildings must not exceed 50 deg. C. with an ambient temperature of 35 deg. C. Research has shown, however, that if shaped acrylic covers are operated at this temperature they may demould and a maximum temperature rise of 35 deg. C. has consequently been specified for all acrylic covers or glazing(4).

Other general requirements are that all fittings shall have terminal boxes, and that connections between the terminal block and the lampholder shall be by asbestos-covered wire or by wire having equivalent insulation.

Wiring in danger buildings must satisfy full flameproof requirements and is in solid drawn conduit throughout. Malleable-iron FLP junction boxes are specified and these are filled with plastic compound. After installation the conduit system is painted.

Double-pole switching is used and, in general, all switchgear is mounted outside the danger building; where there are particularly dangerous hazards the control-gear is positioned outside the mound surrounding the building.

Until 1938 the maximum permitted loading per circuit in danger areas was 300 watts. This was later increased first to 600 watts and then to 750 watts; in the latest regulations no limit is specified, but the practice in this factory is for each circuit entering a danger building to be fused at 3 amperes.

(4.2) Flameproof Lighting Equipment (5)

The flameproof fittings are selected from standard designs approved for use with Group 3 gases. Cast aluminium alloy bodies are generally specified, but where nitrates are present cast-iron is used, as the aluminium alloys corrode rapidly in these locations.

Where fittings operate in atmospheres carrying explosive dusts, there is a danger that dust may be drawn into and through the gap and ignited within the fitting. Although the fitting will withstand the resultant explosion, it is possible for the dust lying within the gap to be ignited, and in turn to ignite the dust outside. To prevent this, it is standard practice to seal the gaps in all flameproof fittings by painting.

(4.3) External Lighting Equipment

The lighting in several Class 1 danger buildings has been improved notably by replacing wall-mounted flameproof fittings with exterior fittings lighting through roof-lights or windows; an experimental fitting for roof mounting is shown in Fig 1. The success of trial installations has been followed by the development of a range of external fittings typified by the 200-watt unit shown in Fig. 2.

A hand-packing cartridge house has recently been relighted with units of this type mounted at 15 ft. and spaced at approximately 12 ft. x 12 ft. The interior of the building was painted off-white, and an average initial illumination of 11-12 lm./ft.^{2} was obtained with a uniformity ratio better than 50 per cent.

Although lamp replacements and general maintenance of these units is somewhat difficult, these disadvantages are more than offset by the greatly improved quality of lighting over a large area of the room.

A more specialised example of lighting by exterior fittings is provided by an

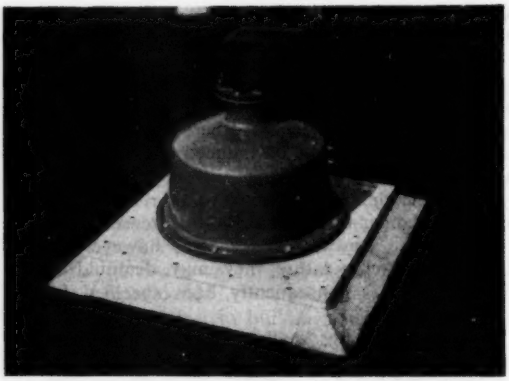

Fig. 1. Experimental fitting for lighting through roof of danger buildings.

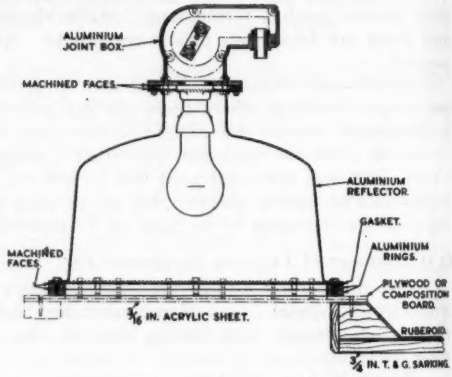

Fig. 2. 200-watt externally mounted fitting for danger buildings.

experimental installation in the nitrating building of a nitro-glycerine plant. In this building—which is included in Class 1 of the Lighting Schedule—a small nitrator and a separator are mounted on a platform some 20 ft. above floor level. The operator must be able to observe the mixing of liquids within the nitrator through a glass top plate and to read a thermometer mounted in this plate. The illumination on the top of the nitrator from wall-mounted flameproof fittings is only 1 lm./ft.^{2}, and to improve this an experimental exterior projection system is being tried. Experiments are being made with two 1-kw. floodlights mounted outside the wall windows and trained to direct their beams on to sheets of polished aluminium fastened to the ceiling; light is reflected from these sheets to the top of the nitrator. With the trial installation the illumination at the nitrator is 20 lm./ft.^{2}. Although from a lighting point of view the system may be thought extravagant, it is justified by the combination of safety with operational efficiency.

(4·4) Dust-tight Equipment

There is, as yet, no scheme for certifying apparatus for use in locations where dust hazards exist. To take advantage of the regulations permitting the use of non-flameproof dust-tight equipment in some buildings, lightweight filament and fluorescent

lamp fittings have been designed and approved specifically by H.M. Explosives Inspector. Typical fittings are shown in Figs. 3 and 4.

The filament lamp fitting has an enamelled aluminium reflector with a dished acrylic cover sealed by a plastic cement between the reflector flange and an aluminium bezel ring. The assembly is bolted together with 8-way screws, and as the joint is permanent the ends of the screws are tapped over after assembly. Temperature tests show that at no point on the cover does the temperature rise exceed 30 deg. C. A typical installation of these units is shown in the photograph of Fig 5, taken inside a cartridge filling plant. The visual task is not severe, and the installation was planned to give an average illumination of 7-8 lm./ft.^{2}, with a rather higher value in the neighbourhood of the mechanical cartridging machine. Two of the wall-mounted flameproof fittings previously used in this building can be seen in the background.

In the fluorescent fitting the lamp is enclosed in an acrylic tube cemented into cast metal rings; spinnings locate the lamp and limit the temperature rise of the tube above the electrodes to 32 deg. C. Both body and reflector are of aluminium alloy and the control gear, with the exception of the starter switch, is located outside the building.

(5) Maintenance of Equipment

Regular and thorough maintenance of fittings and installations is essential to ensure that at all times the equipment conforms with the approved designs.

Installations are inspected and tested on site every six months, the particular building being closed during maintenance. Insulation and earthing continuity tests are made, and fittings are dismantled and examined. All machined faces are cleaned with a non-

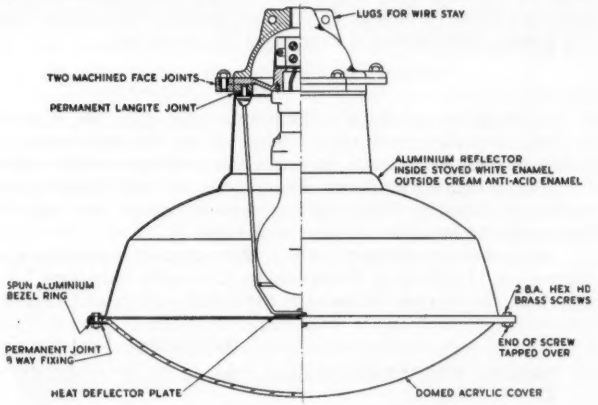

Fig. 3. Dust - tight filament lamp fitting for danger buildings.

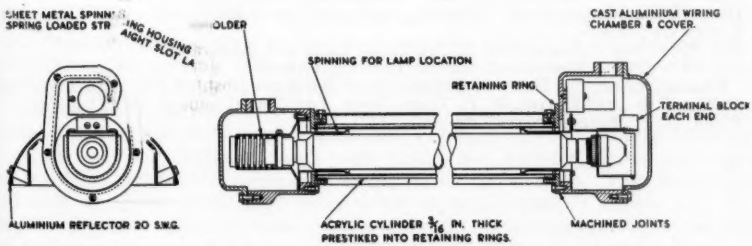

Fig. 4. Dust-tight fluorescent lamp fitting for danger buildings.

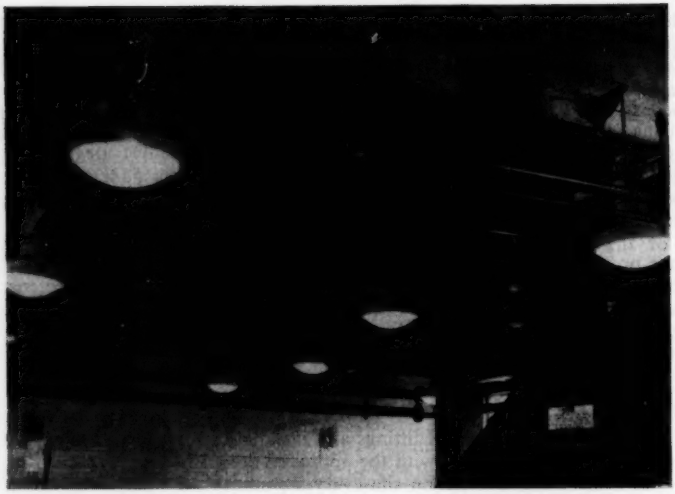

Fig. 5. Installation of filament lamp dust-tight fittings in cartridge-filling plant.

metallic scraper or a non-corrosive fluid and then greased; the gaps in flameproof fittings are checked after re-assembly. Acrylic components are cleaned by washing, dry-polishing being forbidden, as this may induce a dangerous electrostatic charge. Finally, the fittings (and conduit if necessary) are repainted.

(6) Conclusions

Lighting requirements in locations where there are explosion hazards must always be subject to the safety requirements of the industry but, as shown in the explosives industry, study of hazards may lead to the design of more effective fittings and greater freedom in lighting practice. The benefits of such studies are now being realised in the explosives industry, where lighting in many danger buildings has been brought near to the standards usual in ordinary industries.

Such studies will come within the scope of the newly appointed C.I.E. Sub-committees on "Lighting in Hazardous or Corrosive Situations," to whose future work one may look for further advances in the lighting of these factories.

References

(1) Richards, S.W., "Osram Bulletin," **20,** 48, 72, 99 (1942), **21,** 26, 41, 75, 98 (1942), and **22,** 43 (1944).
(2) B.S. 1259: 1945, "Intrinsically Safe Electrical Apparatus and Circuits."
(3) Home Office Memorandum: "Electric Light and Power in Factories and Magazines for Explosives" (1948).
B.S. 229: 1946, "Flameproof Enclosure of Electrical Apparatus."
B.S. 889: 1940, "Flameproof Electric Lighting Fittings."
"Regulations for the Electrical Equipment of Buildings (Inst. of Electrical Engineers).
(4) Collins, P. H., and Harper, W. E., Trans. Illum. Eng. Soc. (London), **15,** 137 (1950)
(5) Paton, A. P., Beama Journal, **49,** 344 (1942).

DISCUSSION

on the papers by
T. S. Jones, S. Anderson, R. W. Middleton and W. E. Harper

Mr. C. W. M. PHILLIPS: To me the most significant thing which has occurred in factory lighting during the last 12 years or so, is the development of lighting for the general environment in addition to the job of lighting for seeing. The I.E.S. Code undoubtedly put lighting for seeing on to a scientific basis, and it is interesting to see how all over the world attention is now being turned to other factors in lighting for industrial efficiency.

I would like to make two quotations from reports made by Sir Wilfrid Garrett, when he was Chief Inspector of Factories, which I think sum up the modern trend towards the problem of lighting for seeing. In the first he said that another remarkable feature of the year had been the growth of public opinion in the direction of insisting on the importance of the general well-being of the factory worker. In the second report he asked whether the country as a whole was giving the same thought to the well-being of work-people compared with the care and attention given to the machines they operate. Every industrial machine was constructed with a pre-determined capacity for load. The only machine in which this was not taken into account was the human machine, and we had never given it the same thought as we had given to machine tools. I think that is a challenge to us, who have to provide the light, to regard the worker as being as important as the machine tools.

Mr. Anderson referred to what is rapidly becoming, in my opinion, a very important part of industrial lighting technique. I suggest that the use to-day of mercury or sodium light on their own is something that we should be slightly ashamed of. The working conditions in a foundry are generally so bad that more care than usual should be taken to give the worker the best lighting possible.

Some large and complicated blended light fittings which are intended for high bay lighting in factories are very difficult to maintain; we are beginning to see the development of lighter and better fittings for blended light, and I hope that this development will continue. I feel that the ideal solution is to try to incorporate the electric discharge lamp and the filament lamp in the same sort of fittings, and to make a composite unit which can be erected and maintained in one piece.

I can find very little to say about Mr. Middleton and Dr. Harper's paper, except that, in my opinion, it should go down in history as a classic reference to this very difficult problem.

I feel that a lot of work has still to be done on factory lighting. As Mr. Jones said, perhaps the subject has been neglected because there is not much glamour in it, but I do not see why a factory installation should not be just as attractive to look at as the modern office installation, and I think a further series of papers on this subject would help materially towards that end.

MR. W. ALLEN: I think it might be of interest to the meeting to hear something of the common lighting practice used in American factories. I had the good fortune to spend a time working with the principal designers of American factories, and I was very surprised at the lighting practice which they have established now.

The design firms with which I spent a short period, are firms of architects and engineers responsible for a very large amount of factory work. These firms employ from 400 to 800 designers each and carry out between them approximately £300,000,000-£400,000,000 worth of factory work in a year. This represents the hard core of middle-of-the-road practice for American factory design, and the first point of interest is that all these people, although in competition with one another and dealing with very large factory plants for all sorts of industries, have, never-

theless, come down to a remarkably standard practice which is very easily and briefly described.

The first thing which struck me was that there is no attempt whatever to tailor the illumination to the average factory. Flexibility is their all-out aim, to make the factory as useful as possible so that it can be adapted from war to peace or changed from one product to another. The illumination is commonly to a standard of 35 lm./ft^2, plus or minus 10. Very little local lighting is ever attempted. Fittings are commonly ranged in rows 10 ft. apart, about 18 ft. above the floor, and are strung along the level of the bottom chord of the trusses. The factories often have no daylight whatever. This practice is emerging for various quite good reasons, one being that it has been found that whenever they do have natural roof lighting, the work-people always have the artificial lighting on anyway.

They string their lighting mostly on "messenger cables," which are about $\frac{1}{4}$-in. steel tight-woven wires across the bottom chords of the trusses. The fittings are either attached direct to these cables, or conduit is fixed first and the fittings attached to this. They use twin lamp fluorescent fittings, and not once in any single factory did I find any upward component of light whatever.

However, I think they expect a revolution in the use of upward light to take place during the next two years, owing to recent findings that fittings which have slots to let light go upward remain much cleaner than closed fittings, due to scouring by the air. The operating temperature of the lamps is said to be nearer the optimum, and the improvement in the efficiency of the fitting compensates a great deal for the slight loss of light which occurs by absorption at the ceiling. It is expected that something like 25 per cent. of the light will be directed upwards, and that fittings will have a cut-off angle of 30 to 35 deg., or more.

I noticed differences in the standard of comfort with different patterns of fittings. Sometimes the fittings were spaced out at intervals, sometimes in continuous rows and sometimes in rows of bay length from 40-50 ft. These produced different discomfort effects. The separated fittings produced the greatest discomfort, and the long lines were fairly uncomfortable by comparison with the medium-length rows, which were really the most comfortable. I found only one trunking system in use, very neat and apparently successful. I saw no louvres in any factory fittings at all.

They say that lighting of the kind described represents approximately 1-2 per cent. of the cost of a factory, and is regarded as a sound investment.

There were one or two other points of interest. They have an internally silvered lamp, 500- or 750-watt tungsten—which I did not hear mentioned at all to-night—which they use in factories where the machine-population density is high and where they want the light straight down through the forest of plant. This type of lamp was very interesting, somewhat glaring, with little upward light and rather sensitive to drips of water, which could fracture the glass. Another unit used their 3-kw. H.P.M.V. lamp in a fitting with very low cut-off and very high discomfort. This unit was generally used with a certain amount of tungsten lighting for the reasons explained by Mr. Anderson.

We have heard a lot about colour in American factories, but the colour-work has been largely misrepresented over here. We had formed the impression that colour in American factories was good, but, in fact, it really hardly exists. We have sent some colour illustrations over there subsequently which have created much interest.

MR. A. R. MCGIBBON: There are one or two questions which I should like to ask. First, when you have two reflectors of the same type for "blended" light, you may have, say, a 500-watt tungsten and a 400-watt mercury vapour lamp—both with G.E.S. caps; how do you avoid the fitter interchanging the lamps? If they were put into the wrong lamp-holders there might be serious trouble.

My second question is that of power factor on the double fitting. Is it quite fair

to claim a correction of power factor? You might have, say, Shop A lit with mercury and Shop B with tungsten, but you cannot then claim a correction of the power factor. I do not think it is fair to say that an overall power factor improvement is achieved by using "blended" lighting.

I have not studied the stroboscopic effect under mixed lighting and, although there must be less flicker than when mercury lamps are used alone, I would like to know how it compares with fluorescent lamp lighting. Presumably the tungsten lamps will bridge the black-out period during the reversal of the cycle.

Can Mr. Middleton and Dr. Harper say how long it takes to relamp the totally enclosed dispersive reflector fitting?

MR. D. A. STRACHAN: Firstly, could Mr. Middleton and Dr. Harper, as a matter of interest, explain the reasons for their company dividing specific danger areas into three classes, and also say on what basis the particular explosives areas are classified.

In the written paper reference is made to the fact that the flameproof fittings used normally are those that meet Group 3 conditions, and I would like to ask if there is any particular reason for the selection of a Group 3 flameproof lighting fitting in preference to those designed to meet the requirements of Groups 1 and 2, especially when under one set of conditions the flameproof gaps are apparently deliberately sealed?

In the written paper reference is also made to the special experimental system used for the lighting of the nitrators, and I am wondering whether consideration has been given to lighting by means of pneumatic-electric (air-turbo) units powered by compressed air. These are available for use with 40-watt mercury discharge lamps, various ratings of tungsten filament lamps, and more recently a fitting has been developed which incorporates 2 x 15-watt tubular fluorescent lamps. Admittedly these units cannot do much more than provide relatively localised lighting, but they are regarded as being exceptionally "safe" since should the cover glass be broken the exhaust air will be some guarantee that the explosive gases and/or dusts will be dispersed from the possible sources of ignition.

Mr. Anderson's paper on blended lighting is a most useful contribution, but there is one point which I would like to make. What percentage of "mix" should one recommend for the different industrial applications and on what basis is the decision to be made? This consideration has been rather relegated to the background by referring to it as being a matter of personal preference, and I feel it is necessary to be somewhat more specific. For instance, under what conditions should the lighting engineer recommend a 50/50 "mix" of mercury/tungsten lighting, or a 70/30 combination with either the mercury or tungsten component dominating?

Perhaps Mr. Anderson could say whether any one "mix" is better than another when taking into account the class of industrial interior and the particular work performed therein. Economic factors are no doubt important, and I will be interested to have Mr. Anderson's further observations on this aspect of the problem.

MR. C. E. GREENSLADE: We are, of course, concerned with mixed blended light in the ordinary tubular fluorescent lamp. You have the general fluorescent spectrum together with the line spectrum of the mercury. I would submit that it is not a question of the colour, the red content of the blended light or personal preference, but of satisfying the eye. It can be readily demonstrated by experiment that if one is looking at a series of figures or at a drawing at a fixed distance, when you look at a particular word the eye defocuses to the extent of ¼ in. I think that the leading colour on which the eye focuses is that whose wavelength is 554 millimicrons. We have not been bothered with this phenomenon in the days of tungsten filament lighting, but with fluorescent lighting there is a green line in the composite spectrum

and when your eyes are very tired the thing you are looking at goes blank but the surround is very sharp. If, however, you then change to tungsten light the effect disappears. It would seem that in any fluorescent lighting installation a proportion of filament lamp lighting is necessary if this effect is to be overcome. A satisfactory blend appears to be given by one 60-watt tungsten lamp to two 80-watt fluorescent lamps.

MR. S. S. BEGGS: I remember before the war that a blend of 80-watt plain mercury lamps and tungsten filament lamps was used for shop window lighting, and the installations were rather attractive. Is there any reason why these have disappeared, because the idea still seems attractive to me?

I noticed in one of the fittings shown by Mr. Middleton and Dr. Harper that the transparent covers were acrylic plastic. Is there any advantage in this, particularly in the fitting mounted externally? Plate glass might be equally serviceable, and would overcome the tendency to accumulate dust by static charge.

MR. A. G. PENNY: Mr. Anderson referred—and I think Mr. Phillips also—to the very great importance of having good colour, and that is obviously the reason for the idea of blended light. I think, however, that we must bear in mind that in many instances, where the processes are dirty, where the things to be handled have a low colour content and where colour discrimination is not important, there is not very much justification for a really good colour of light, especially as all the methods of improving the colour of light involve introducing into the spectrum either blue or red light to which the eye is not very sensitive. This means you are facing the problem that, if you wish to improve the colour, you have to lower the efficiency of the lighting installation and therefore increase the cost. I suggest, therefore, that very often in the heavy engineering world there is no real justification for good colour, and that any money saved by the use of high efficiency lamps could be more profitably utilised to improve the installation in other ways, as, for instance, by increasing the level of illumination, by the reduction of glare, etc.

Secondly, I should like to take up Mr. Allen's point about lamps with a reflecting surface on the inside of the bulbs. I think he gave the answer himself when he pointed out that the Americans have found it necessary to have a shield over the lamp to prevent breakage from water dripping on it. Water drips on most lighting fittings in heavy industry, and by the time you have put a cover over the lamp you might as well incorporate the reflector in the cover. Nevertheless, the permanently clean reflecting surface has advantages, and it may be that for dirty places the lamps will be attractive.

Mr. J. S. McCULLOCH: I disagree most emphatically with Mr. Penny regarding whether or not colour of lighting matters in industrial premises. In opening the discussion Mr. Phillips brought out the point that the workman is a machine, and subsequently Mr. Allen in his contribution made it quite clear that the Americans paid great attention to the psychology of work-people when designing the lighting installation. The workman is a human machine, and in the past we have not given him much attention. In my experience in the heavy industries the British workman does not like mercury vapour lighting as it distorts the colour of his work and his surroundings and of his workmates. I am sure Mr. Penny would not like to work in it—why should the workmen have to do so?

My final point is in connection with one of the slides which Mr. Anderson showed on blended lighting in a plastics factory. This was an installation with which I was concerned some seven years ago. The tungsten filament and mercury vapour lamps are housed in two separate fittings mounted at about 2 ft. 6 in. centres, and we found

that beneath the open iron grating surrounding the high presses, the light beneath was split into the two colours in a mosaic pattern. We know now that closer mounting —or, better still, combined fittings—will reduce considerably this colour-shadow effect.

Mr. L. H. HUBBLE: Referring to Mr. Anderson's paper, he showed a particular distribution from a type of blended light unit in which the profile of the horizontal mercury-lamp reflector is intentionally concentrating. I would like to point out that these reflectors are easily—indeed, instantly—removable, and can be made to any desired contour within the optical limits. It is, therefore, a little wrong to compare that particular type of blended light unit with another sort of blended light unit on the assumption that its distribution must of necessity be as shown.

Mr. T. S. JONES (in reply to the discussion on his paper): I was interested in the remarks regarding American practice because they do confirm my own findings that the general lighting standards in United States industries are much lower than in our own. It was mentioned that there was no attempt to "tailor" the lighting—I agree wholeheartedly, for the normal American practice appears to pay far less attention to the visual task than is indicated in their journals. I am very pleased that they are now beginning to realise the value of upward lighting; our standards in that respect are much higher.

I do not like the idea of continuous coupling of individual fittings. I think far greater flexibility will result from continuous trunking, which is a very versatile system. The problem of long converging lines can be overcome by proper arrangements of the initial layout, and in very long shops it is usual to mount continuous trunking along the length of the trusses, i.e., across the building.

I am rather surprised at the suggestion that there should be a 25 per cent. upward component of light. It sounds as though they are going too far, and will probably come back to about 10 per cent. in the end. I think a 30-deg. cut-off is reasonable for many situations.

An interesting point was made by Mr. Allen when he mentioned the greater efficiency of fittings having slotted tops. This applies particularly to two-lamp fittings in which the Americans are mainly interested. It is a fact that with two-lamp fittings, due to the better lamp-wall temperature, a somewhat higher efficiency results with a well-designed slotted top reflector than with a closed top reflector, but this is not so noticeable with a single-lamp fitting.

Regarding colour, I am sorry that Mr. Allen did not visit the factory of the Cleveland Graphite Bronze Co., which I am sure he would have remembered. It is a windowless factory, and the colour scheme is, in my opinion, excellent.

MR. S. ANDERSON (in reply to the discussion on his paper): I think the possibility, suggested by Mr. McGibbon, of getting the lamps wrongly inserted in a blended light fitting can be avoided by having the appropriate lamp details clearly printed against each holder. From this point of view it is unfortunate that both types are similarly capped in the large sizes; in the smaller sizes the three-pin B.C. cap safeguards the discharge lamp satisfactorily.

From the supply authority's point of view, I think it matters little how the load and power factor vary in different parts of the consumer's installation provided that the overall power factor at the authority's terminals is satisfactory. The effect of having a unity power factor load in one part of the factory and a low power factor load in another may be open to objections from the consumer's standpoint, but, in any case, my statement referred to an installation of blended lighting where both tungsten and discharge lamps were adjacent and fed through common final sub-circuit

wiring. I can see no possible objection to such an arrangement being operated without further power factor improvement by means of capacitors.

The assessment of stroboscopic effects is largely a matter of personal opinion. My own experience is that with a reasonable blend of tungsten and discharge lamp light it is definitely less noticeable than with either fluorescent or plain mercury light alone.

I think a part of the answer to Mr. Strachan's query on suitable proportions for blended light has been given by Mr. Greenslade, but would remind him that I did suggest something between equal wattage and equal lumens. The precise blend does not appear to me to be critical. In a large heavy engineering shop I would expect a higher proportion of mercury light to be acceptable than in a light assembly shop or a laundry.

Economically, a blended light system will practically always have the advantage over a fluorescent lamp system, and often over a tungsten lamp system unless the cost of power is low. Naturally, since the mercury lamp is more efficient than the tungsten lamp, increasing the proportion of mercury lamp wattage will lead to economy in power consumption with blended light for any given illumination.

I am not qualified to comment on the visual effect described by Mr. Greenslade, except to say that I have not consciously experienced it with any type of lighting, but I gather he feels that a blended light is preferable in this respect.

The disappearance of blended light from shop windows is as much a mystery to me as to Mr. Beggs, but I have seen one or two examples since the war where this type of lighting was still in use.

Mr. Penny's feeling that there is little or no justification for blended light in heavy engineering is opposite to that of Mr. McCulloch. My experience is that a growing proportion of users are not satisfied with plain mercury light on the score of colour, and my views are in accord with those expressed by Mr. Phillips and Mr. McCulloch.

I appreciate Mr. Hubble's point regarding the flexibility of the blended light unit shown in Fig. 5. The possibility of swinging the mercury lamp reflectors through 90 deg. may be valuable on occasion, though the distribution of the tungsten component is not capable of similar adjustment.

DR. W. E. HARPER (in reply): In reply to Mr. McGibbon, relamping of the filament lamp dust-tight fitting takes approximately three minutes. In this time the two flanges are separated, the lamp replaced, and the flanges cleaned, regreased and bolted together.

Mr. Strachan's query regarding the classification of explosives buildings requires a detailed reply.

Class 1 lighting is always *preferred* where there are explosives in a building. Class 2 or Class 3 lighting may be used when it is impracticable to provide adequate illumination by Class 1 equipment. It is the responsibility of the factory manager to decide which type of lighting is to be used.

In buildings where nitroglycerine can evaporate and condense, or where comparatively dry, sensitive explosive powders are processed or stored, lighting by Class 1b wall mounting fittings only is usually permitted. For buildings of this type, it is considered necessary to limit roof vibrations to a minimum and as the number of windows is limited, lighting by Class 1a fittings is generally ruled out.

Class 1b fittings are also preferred for all magazines, other than those in which packed explosives sufficiently insensitive to detonation by impact of a fitting falling on to the containers are stored, and in buildings where, although the process would permit the use of externally mounted fittings, the roof construction or window space is unsuitable.

The quantity of explosive stored in a building or magazine must also be taken

into account when deciding the type of lighting to be installed. In the event of an explosion, pendants and external roof fittings can act as projectiles, and the force of projection is obviously related to the quantity of explosive in the building.

The Class 1a fittings described in the paper can now be used in Class 1 buildings free from the above restrictions, where previously only wall-mounted fittings were permitted.

In Class 2 buildings the use of pendant flameproof well-glass units is permitted where there may be a risk of solvent vapour from the operation, provided that (i) the fittings can be positioned to prevent, under normal working, foreign matter falling into materials should the well-glass break, and (ii) the roof construction can provide adequate support for the fittings. Wall-mounted flameproof fittings are used in Class 2 buildings where these conditions cannot be satisfied, and where—owing to unsuitable wall construction—Class 1b fittings cannot be used.

Class 3 lighting is comparatively new, and to date is restricted to buildings in which the risks are not severe. As experience is gained it is hoped to increase the use of Class 3 fittings, but for the time being they are installed only in buildings where there are no solvent vapours, where the quantities of dust are very small (although they may increase under abnormal conditions), and where the dust is comparatively insensitive to the friction which accompanies the removal and replacement of bolts or setpins.

The regulation that only Group 3 flameproof equipment can be used in this plant is based on the fact that although the hazards include those of more than one of the Groups detailed in B.S.229, it is sound practice to confine all flameproof equipment to one category, namely that of the highest Group concerned. Moreover, since there is no equipment certified to cover the combined hazard of Group 1-3 gases and dust, it is company policy to use equipment certified for the next higher Group to that required for the gas hazard alone, when this is possible. Sealing of flameproof equipment by painting does not affect the issue.

Mr. Strachan suggested that intrinsically safe pneumatic-electric units might be used for lighting in locations such as the nitrating plant described in the paper, but these fittings do not comply with the requirements for Class 1 buildings. The experimental system using projectors mounted outside the danger area makes unnecessary the use of FLP or intrinsically-safe equipment. If pneumatic-electric units were installed in other danger buildings, the escape of air in the event of a cover glass breaking would cause dispersion of dust in the vicinity of the fitting and might introduce foreign matter into the building; impurities must be kept out of explosives buildings. As a matter of interest, the polished aluminium sheets used in the nitrating plant for reflecting light from the projectors are being replaced by white rigid p.v.c. sheet.

Mr. Beggs queried the use of acrylic covers in some fittings. Dust accumulation from static charge does not cause undue trouble, and acrylic covers have the advantages that (i) particles from a broken cover constitute a much safer contamination of explosives than particles from a broken glass cover, and (ii) the use of acrylic covers implements the general policy of keeping the weight of fittings as low as possible.

Since the paper was written, two modifications in installation practice have taken place which may be noted. First, authority has been sought and obtained for the use of heavy gauge screwed welded galvanised conduit with dust-tight fittings. Previously, solid-drawn conduit was used. Second, where dust hazards only exist, dust-tight galvanised malleable iron junction boxes are to be used in place of FLP boxes. The new boxes will comply with the requirements of the Home Office for such situations.

Opening Sessional Meeting in London

The opening meeting of the 1951-52 session took place at the Royal Institution, Albemarle-street, London, on Tuesday, October 14. The chair at the opening of the meeting was taken by the retiring President, Mr. J. G. Holmes.

After the preliminary announcements Mr. Holmes said that the Council had decided to confer Honorary Membership of the Society upon Professor J. T. MacGregor-Morris, who had been a member of tne Society since 1909 and President in 1940. Prof. MacGregor-Morris had managed to be a most active member of the Society in spite of his many other activities. He had held many senior academic positions in London University and he continued to be a most useful member of the Society's Education Committee. Mr. Holmes said that the award was most appropriate at this time as Prof. MacGregor-Morris was about to celebrate his 80th birthday.

The chairman said, quoting from the citation, that this award was made to Prof. MacGregor-Morris "in recognition of his many services to the Society and in acknowledgement of his pioneering work in illuminating engineering and photometry, particularly his research on the carbon arc as a standard of light." The certificate was then presented to Prof. MacGregor-Morris, who expressed his warm appreciation of the action of the Council and members of the Society in conferring this honour upon him.

Mr. Holmes then said that he had also been asked by the President of the I.E.S. of the United States of America to present to Mr. J. M. Waldram a certificate of Fellowship of that Society. The certificate was then presented to Mr. Waldram, who made acknowledgement.

The chairman then called upon Dr. W. J. Wellwood Ferguson to present his Presidential Address.

Dr. Ferguson endeavoured in his address to indicate the main approaches to the problem of illuminating engineering and referred to the physical, physiological and psychological aspects. The lighting engineer, he said, seeks for formulae whereby the recommendations of the physiologist may be converted into terms of the illumination, or brightness, necessary for the particular tasks in hand. To the manufacturer the problem is one of designing and constructing the necessary light sources and fittings with which this demand may be met. Whether or not the result is successful depends on many variable factors, and while the result may be efficient it may at the same time fail to be either economic of aesthetically satisfying. The artistic approach, he said, is of itself a fascinating study but even more full of pitfalls and vagaries of human variation.

A vote of thanks to Dr. Ferguson was proposed by Mr. H. C. Weston and seconded by Mr. D. A. Strachan and carried with acclamation.

On taking the chair, Dr. Ferguson expressed his thanks to the Society for conferring this honour upon him and expressed the thanks of the Society to Mr. Holmes for the way in which he had conducted the affairs of the Society during the past year. He then welcomed the Vice-Presidents for the coming session, Mr. A. G. Higgins, Mr. E. C. Lennox, Mr. A. H. Owen, Mr. J. F. Stanley and Mr. W. J. P. Watson.

The President then announced that the Council had decided to award the Leon Gaster Memorial Premium to Mr. J. S. McCulloch for his paper entitled "Lighting of Shipyards," and the award and certificate were presented to Mr. McCulloch.

The President recalled that the suggestion had been made that some memento of their year of office should be presented to Past-Presidents. This matter had been

considered by the Council as a result of which it had been decided that Past-Presidents on retiring from office should be presented with a replica of the Presidential Badge which, it was decided, was to be awarded to all Past-Presidents. He then called upon the following Past-Presidents to receive their badges: Mr. A. Cunnington, Dr. S. English, Mr. F. C. Smith, Prof. J. T. MacGregor-Morris, Mr. R. O. Ackerley, Mr. E. Stroud, Mr. H. C. Weston, Mr. J. M. Waldram, Dr. J. N. Aldington and Mr. J. G. Holmes. The President reported apologies from Sir John Parsons, Dr. J. W. T. Walsh, The Earl of Mount Edgcumbe, Mr. A. W. Beuttell, Mr. W. J. Jones, Dr. H. Buckley and Mr. L. J. Davies, who were unable to be present.

The meeting then closed.

Printed by
ARGUS PRESS, LTD.,
Temple-avenue and
Tudor - street,
London, E.C.4,
England.